Model-Data Intercomparison for Marginal Sea Overflows

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LONG-TERM GOALS

The long-term goal of this project is to enhance the level of understanding of the dynamics of overflows, which are characterized by high degree of variability and mixing near strategic straits connecting various marginal seas and oceans.

OBJECTIVES

1) To complement field studies and to develop a better understanding of the characteristics of mixing and its influence on the subsequence fate of the overflows.
2) To address the fundamental issue of entrainment of a plume in the presence of rotation and ambient stratification.
3) To develop parameterizations of mixing for ocean general circulation models.
4) To explore the large-scale impact of mixing in overflows.

APPROACH

The research has been been carried out using a combination of oceanic data, high-resolution nonhydrostatic numerical model, and analytical techniques.

WORK COMPLETED

The primary accomplishments during this grant period are as follows:

1) Publication of a paper in the Journal of Physical Oceanography summarizing an analytical investigation of the characteristics of β-plumes driven by localized mixing in overflows (Özgökmen and Crisciani, 2001).

2) Publication of a paper in the Journal of Physical Oceanography describing the validation and benchmarking of a two-dimensional, nonhydrostatic numerical model using laboratory experiments bottom gravity currents (Özgökmen and Chassignet, 2002).

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3) A model-data intercomparison study is completed between the nonhydrostatic model and part of the Red Sea overflow from REDSOX (NSF-funded) field program. This manuscript is submitted for publication in the Journal of Physical Oceanography.

RESULTS

Motivated by the fact that overflow processes, which supply source waters for most of the deep and intermediate water masses in the ocean, pose significant numerical and dynamical challenges for ocean general circulation models, an intercomparison study is conducted between the field data collected in the Red Sea overflow under the REDSOX-1 observational program and a high-resolution, nonhydrostatic process model. The intercomparison study is focused on the part of the outflow that flows along a long narrow channel, referred to as the "northern channel", which naturally restricts motion in the lateral direction such that the use of a two-dimensional model provides a reasonable approximation to the dynamics. This channel carries about the two-thirds of the total Red Sea overflow transport, after the overflow splits into two in the western Gulf of Aden.

The evolution of the overflow in the numerical simulations can be characterized in two phases: the first phase is highly time-dependent, during which the density front associated with the overflow propagates along the channel. The second phase corresponds to that of a statistically steady state. The primary accomplishment of this study is that the model adequately captures the general characteristics of the system: (i) the gradual thickening of the overflow with downstream distance, (ii) the advection of high salinity and temperature signals at the bottom across the channel with little dilution, and (iii) ambient water masses sandwiched between the overflow and surface mixed layer (Fig. 1,2).

To quantify mixing of the overflow with the ambient water masses, an entrainment parameter is determined from the transport increase along the slope, and expressed explicitly as a function of mean slope angle. Bulk Richardson numbers are estimated both from data and model, and are related to the entrainment parameter. The range of entrainment parameter and its functional dependence to bulk Richardson number in this study are found to be in reasonable agreement with those reported from various laboratory experiments, and that based on measurements of the Mediterranean overflow.

Finally, the results reveal a complex dynamical interaction between shear-induced mixing and internal waves, and illustrate the high computational and modeling requirements for numerical simulation of overflows.

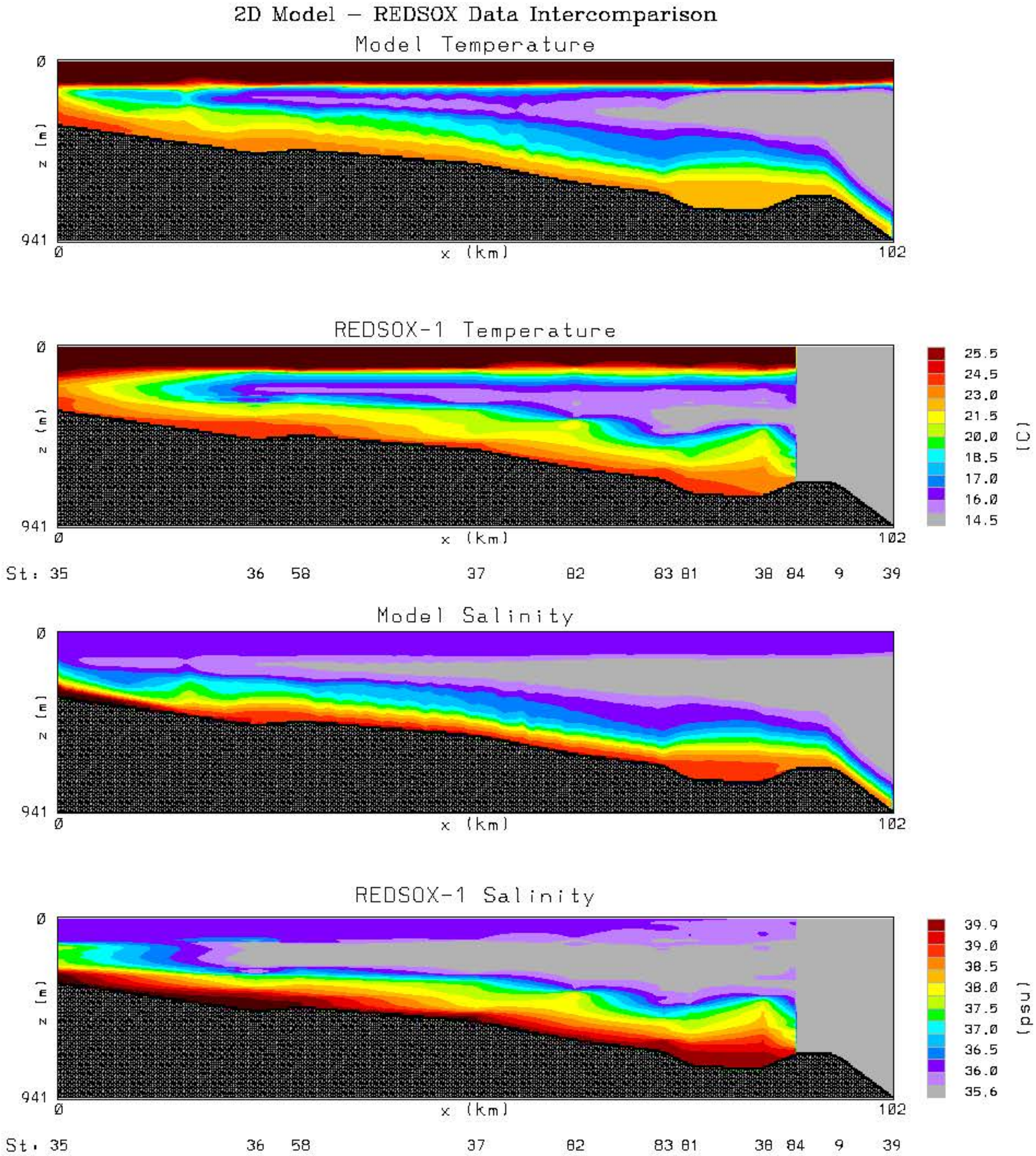

Figure 1: Comparison of salinity and temperature distributions from the model and from REDSOX-1 observations.

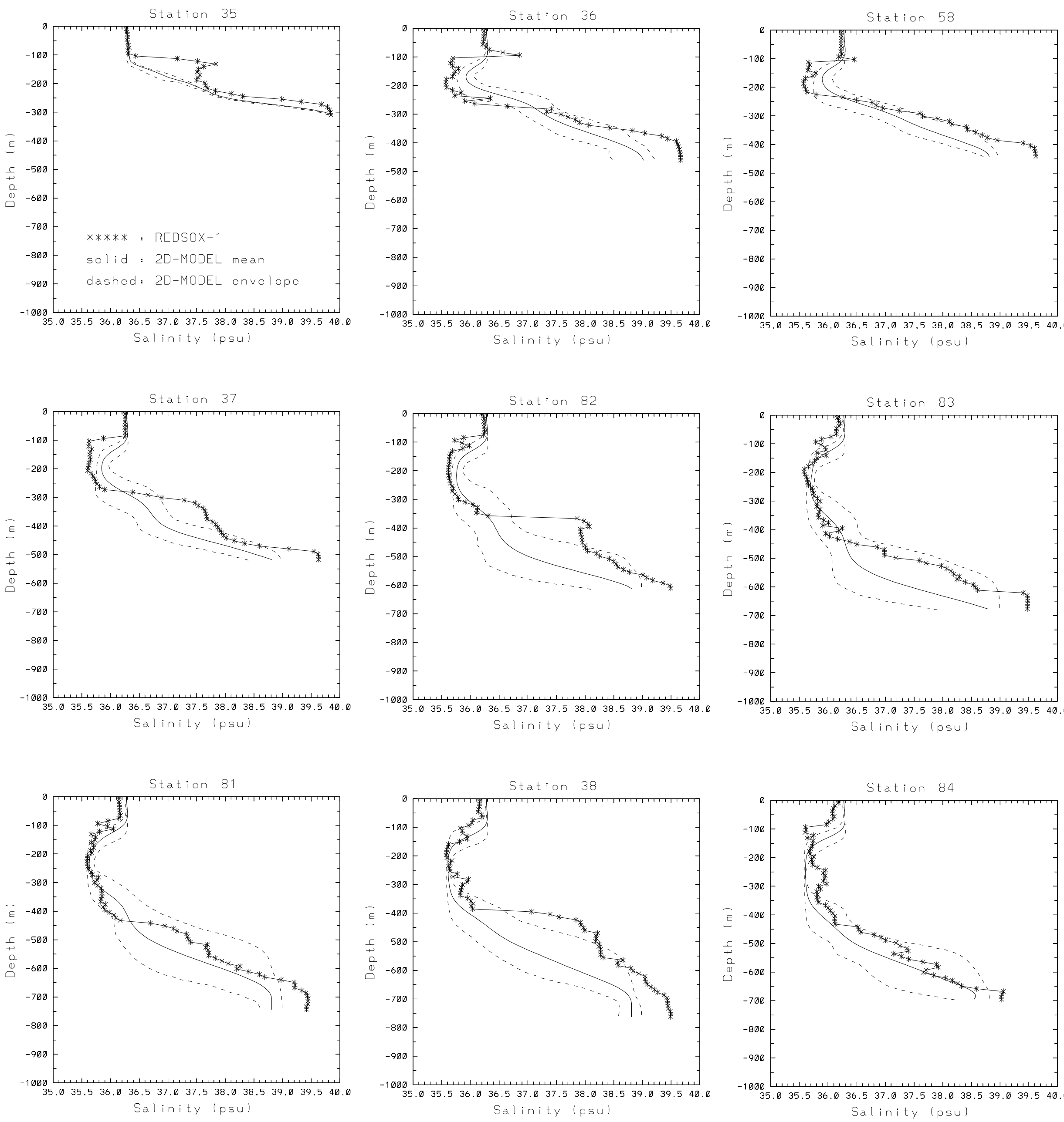

Figure 2: Comparison of salinity profiles from REDSOX-1 observations and the model. Salinity (in psu) is plotted as a function of water depth (in m) at each REDSOX-1 station within the model domain (curves marked with ""). Solid curves show time-averaged model profiles, and dashed curves mark the range of variability of the profiles in the model simulation during equilibrium state.***

IMPACT/APPLICATIONS

Oceanic overflows are characterized by high levels of turbulence and mixing near strategic straits connecting various marginal seas and oceans. A detailed understanding of such phenomena is not only important for submerged equipment but also for large-scale ocean circulation and climate-related studies.

TRANSITIONS

Simulation results complement the understanding and interpretation of field data from REDSOX. Results also promote the need for better parameterizations not only in general circulation models, but also in process-oriented models.

RELATED PROJECTS

(i) Red Sea Outflow Experiment (REDSOX), PIs: W. Johns, H. Peters, A. Bower, D. Fratantoni, NSF-OCE.

(ii) Dynamics of boundary currents and marginal seas, PI: W. Johns, N00014-95-1-0025.

PUBLICATIONS (2001-2002)

Özgökmen, T.M., E.P. Chassignet and C. G. H. Rooth, 2001: On the connection between the Mediterranean outflow and the Azores Current. *J. Phys. Oceanogr.*, **31**/2, 461-480.

Özgökmen, T.M., and F. Crisciani, 2001: On the dynamics of β-plumes. *J. Phys. Oceanogr.*, **31**/12, 3569-3580.

Özgökmen, T.M., and E.P. Chassignet, 2002: Dynamics of two-dimensional turbulent bottom gravity currents. *J. Phys. Oceanogr.*, **32**/5, 1460-1478.

Özgökmen, T.M., W. Johns, H. Peters, and S. Matt, 2002: Turbulent mixing in the Red Sea outflow plume from a high-resolution nonhydrostatic model. *AGU Ocean Sciences meeting*, QS1Q-04, Honolulu.

Özgökmen, T.M., W. Johns, H. Peters, and S. Matt: Turbulent mixing in the Red Sea outflow plume from a high-resolution nonhydrostatic model. Submitted to *J. Phys. Oceanogr.*